X-320-63-26

N63 20208

CODE-1

37p.

THE PURPOSES OF ENVIRONMENTAL TESTING FOR SCIENTIFIC SATELLITES

OTS PRICE

XEROX $ 3.60 ph

MICROFILM $ 1.31 mf.

FEBRUARY 12, 1963

NASA

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

THE PURPOSES OF ENVIRONMENTAL TESTING FOR SCIENTIFIC SATELLITES

FEBRUARY 12, 1963

JOHN H. BOECKEL, ASSOCIATE CHIEF
TEST AND EVALUATION DIVISION
OFFICE OF TECHNICAL SERVICES

TABLE OF CONTENTS

X-50,266

THE PURPOSES OF ENVIRONMENTAL TESTING FOR SCIENTIFIC SATELLITES

INTRODUCTION

Reliability is an attribute of a device which cannot be directly measured. In treating reliability numerically we introduce the concepts of probability and define reliability as:

> "The probability of a successful operation of the device in the manner intended and under the conditions of intended customer use."[1]

This definition (and many similar ones) leaves a large number of open questions. These lie chiefly in determining the required level of "probability" and in defining criteria for "success".

The required level for the reliability of a satellite is a function of its mission. The following paper will be directed toward an exposition of the reliability and environmental testing problems as they apply to scientific satellites as distinguished from those spacecraft used for manned space-flight or for military purposes. In general, the manned and military missions require a considerably higher degree of reliability than does the scientific one. Unreliability in a scientific satellite implies loss of data, in a manned satellite loss of life, in a military satellite risk to the nation's defense posture. On the other hand, the scientific satellite is usually more complex, is developed in a short period of time, and carries instrumentation at the highest levels of the state-of-the-art. The problems of reliability assessment are therefore of comparable difficulty for all three categories but are approached from slightly differing points of view.

---

[1] Lloyd, D. K. and Lipow, M., Reliability: Management, Methods and Mathematics. (Prentice-Hall: Englewood Cliffs, New Jersey, 1962), Page 20.

The scientific satellite has as its objective the making of fundamental measurements which cannot be made from earth. In some cases, these measurements must be made in-situ; in others, we must raise our instruments above the distorting effects of the earth's atmosphere, magnetic field, and ionosphere. A given satellite usually carries a set of experiments all intended to make simultaneous measurements of interest in a given discipline. We have Explorer VIII making direct measurements of the ionosphere, Explorer XI orbiting a gamma ray telescope, Explorer XII measuring energetic particles, and the Orbiting Solar Observatory measuring electromagnetic radiation from the sun as examples. A listing of satellites and space probes launched by the Goddard Space Flight Center (GSFC) as of December 1962 is attached.

In broader terms, Dr. Robert Jastrow has summarized the intent of NASA's scientific investigations in space as follows:

> "Although they involve many questions in physical science, nonetheless most of the matters under investigation by space flight vehicles may be grouped around a relatively small number of central problems:
>
> First, problems relating to the structures of stars and galaxies: stellar evolution, nucleosynthesis, the cosmic abundances of the elements.
>
> Second, the origin and evolution of the solar system, the formation of the sun and planets, and the subsequent history of the planetary bodies.
>
> Third, the control exercised by the sun over the atmosphere of the earth, the structure of the upper atmosphere, and the causes of weather activity in the lower atmosphere."[2]

---

[2] Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration, Nov. 1-3, 1962, (Chicago, Illinois), Volume I.

The level of reliability which should be required of a satellite whose purpose is to gather data applicable to these fundamental problems is a difficult one to set. In the terms of usual time scale for the evolution of new scientific theory from basic data, the scientist is not particularly interested in whether the data comes from today's launching or the launching of the back-up flight unit a few months hence. (Favorable planetary orbital conjunctions are an obvious restriction on this freedom in time. However, the "launch window" is often sufficiently long to provide for a second launching.) The circumstance of a back-up unit then gives an impression that all we require is a reasonably high probability that at least one of two units should be successful.

Another problem arises when we consider the question of what constitutes success. Since we are flying perhaps five experiments on even a small satellite, we do not require that all work perfectly before calling the shot a success. Furthermore, the required duration for acceptable operation should be defined. For some satellites, transmission of data for a few orbits might suffice. For others which hope to determine expected ranges of the measured parameters, months may be needed.

On the basis of scientific considerations alone assignment of reliability requirements is impossible. Reliability is fundamentally a ratio. It is used to weigh risk against investment. Traditionally, scientific investigation has been concerned with the gathering of accurate data, subjecting it to rigorous analysis, fitting it to theoretical hypotheses and subsequently gathering further independent data for verification of the results. Employing satellites as a scientific tool has changed one factor in this process markedly: the cost of making the experiment. Expensive tools have been used before: e. g. the cyclotron. However, the "one-shot" nature of the satellite experiment is probably paralleled only by the investigations of the effects of atomic explosions.

By introducing cost considerations, we begin to have a basis for stating the satellite reliability problem. A level of performance must be obtained which balances the high costs of an individual firing against the need for obtaining timely accurate data with a package of minimum weight containing exotic instrumentation.

Typical scientific satellite costs are given below:

TABLE I *

Satellite	Vehicle	Spacecraft Cost	Vehicle Cost
International II	Scout	M$ 1.3	M$ 1.0
Explorer XII	Delta	2.7	2.5
POGO	Thor-Agena	11.5	6.5
Advanced OSO	Atlas-Agena	17.0	8.3

* These numerical values are estimates and must not be taken as authoritative.

By taking the total dollars budgeted and the total weight of satellites in orbit, one may derive an estimate of $50,000 per pound for all efforts to date.[3] It is clear then that one cannot be promiscuous in launching unproven designs.

A TYPICAL SCIENTIFIC SATELLITE - EXPLORER XII

Before proceeding further with a discussion of reliability, a brief exposition of a typical satellite's make-up is in order. Explorer XII launched on August 15, 1961, has been chosen as an example. As described in the attached summary, it carried some five experiments and provided 2568 hours of real-time data before it ceased transmitting.

Figure 1 is a picture of Explorer XII. Figure 2 shows a block diagram of the system. A weight breakdown by function is as follows:

---

[3] New, J. C. Achieving Satellite Reliability Through Environmental Tests, (Proceedings of the Institute of Environmental Sciences) April 1963 - (to be published).

TABLE II

	Weight (Lbs.)	Per Cent of Total Weight
STRUCTURE	22.5	27.0
TELEMETRY	5.5	6.6
POWER SUPPLY	21.7	26.0
INTERFACE HARDWARE	6.0	7.2
EXPERIMENTS	27.5	33.0
TOTAL	83.2	99.8

This basic satellite with different experiments was also successfully flown as Explorers XIV and XV.

From a reliability point of view there is nothing striking thus far. We have an electronics package weighing little more than a typical television set. However, looking more closely, we find an impressive number of electronic parts.

TABLE III

Capacitors (Fixed)	1,121
Capacitors (Variable)	9
Diodes	813
Resistors (Fixed)	2,633
Resistors (Variable)	11
Transistors	1,063
Connectors	70
Inductors	93
Transformers	43
Crystals	2
Switches	10
Solar Cells	6,144
TOTAL	12,002

One may take for granted that these parts are taxed as heavily as the designers dare in an effort both to minimize weight and perform sophisticated tasks.

MATHEMATICAL MODELS

Lloyd and Lipow[4] discuss the establishment of mathematical models of physical systems wherein the reliability of each function of the system can be estimated for a point in time. This type of model can be extended to cover the probability of successful operation as a function of time. The reliability assessment of the Mariner spacecraft by the Planning Research Corporation is a good example of this technique.[5]

After the model is established, empirical data for the expected performance of the individual parts (under predicted electrical and "environmental" stresses) are inserted. These data are almost always in terms of failure rates as defined for an exponential distribution.[6] By suitable combination of these rates, one may derive the expected "mean time between failures" for the complete system. Table IV gives such predictions for the Explorer XII spacecraft.

There is a fundamental difficulty in employing the output of the mathematical model of a satellite: the applicability of the empirical data used. Because of the rapid pace of electronic part development, the large sample sizes, uniform populations and statistical product quality control, which must form the basis for part performance prediction, do not apply. Or as I heard it stated recently; "The model is good: if only we had some decent part data". NASA is now beginning to try to assemble a "preferred parts list" for space applications. However, it is very difficult to tell the designer that he must wait months for qualification testing when a supplier markets a new high performance device.

---

[4] Lloyd & Lipow, Op. Cit. Chapter 9.

[5] Planning Research Corporation, <u>Reliability Assessment of the Mariner Spacecraft</u>, December 17, 1962. PRC R-293

[6] Lloyd & Lipow, Op. Cit. Page 137.

TABLE IV

Satellite Subassembly	Mean Time Between Failures
Over Voltage Regulator	0.085×10^6 hrs.
Current Monitor	0.16×10^6 hrs.
Battery "A" & "B"	2.5×10^6 hrs.
Recycle Timer	0.051×10^6 hrs.
Command Program Switch (essential components)	0.12×10^6 hrs.
Command Program Switch (all components)	0.061×10^6 hrs.
Regulator Converter	0.012×10^6 hrs.
Encoder Converter	0.044×10^6 hrs.
Digital Oscillator 1 (optical aspect)	0.030×10^6 hrs.
Digital Oscillator 2 (cosmic ray)	0.033×10^6 hrs.
Digital Oscillator 3 (cosmic ray)	0.022×10^6 hrs.
Digital Oscillator 4 (S.U.I.)	0.031×10^6 hrs.
Analog Oscillator 1 (Ames)	0.046×10^6 hrs.
Analog Oscillator 2 (I&E)	0.045×10^6 hrs.
Analog Oscillator 3 (Magnetometer)	0.046×10^6 hrs.
Analog Oscillator 4 (Performance Parameters)	0.020×10^6 hrs.
Analog Oscillator 5 (Performance Parameters)	0.016×10^6 hrs.
Transmitter	0.030×10^6 hrs.

At present then, the mathematical prediction is only indicative. The intent in setting up a model of a satellite system is to highlight those elements of the assembly which have the greatest impact on system performance rather than to make accurate quantitative predictions.

TESTING PHILOSOPHY

Satellites are not only "one-shot", they are virtually "one of a kind". Usually a prototype, a flight unit and a back-up flight unit are the only complete assemblies that are made. Thus, the variations between individual elements and the unpredictable interactions and dependencies which are the curse of accurate mathematical analysis tend to dominate the problem. One cannot, therefore, predict flight unit performance on a statistical basis from the results of previous testing. In this situation, rigorous testing of <u>the actual units to be flown</u> becomes a necessity.

The purpose of environmental testing in a satellite program is to establish the suitability for flight of a given "flight unit". Hereafter, we will deal almost entirely with systems tests. Subassembly testing under environmental stresses more severe than those expected in actual use is presupposed. It must be noted at this point that the difficulty of conducting adequate subassembly tests of complicated new devices on the time scale of the typical satellite development program is frequently overwhelming. This results in the presence in early systems tests of subsystems which may never have experienced environmental exposures. This is particularly true of the experiments themselves.

The emphasis on systems testing is sound on a statistical basis as pointed out by Lloyd and Lipow in their discussion of experimentation and testing.[7] There is one point, however, which the authors do not discuss. This is the fact that in tests of a complete system, no information is generated as to the input and output sensitivities of individual subassemblies. A marginal condition may exist and remain undetected. Subassembly testing must cover this problem.

---

[7] Ibid., Pages 350 & 371.

SYSTEMS TEST OBJECTIVES

The systems test program for a satellite has six goals:

(1) Verification that novel or unproven designs meet performance requirements and have a satisfactory life expectancy.

(2) Verification that particular samples of previously employed hardware are suitable in a new application.

(3) Elimination of defects in design, material or workmanship (i.e. finding the weak links in the chain).

(4) Discovery of unexpected interactions between subassemblies when the system is exposed to environmental stress.

(5) Training of personnel who will be responsible for the satellite at the launching site and those who will be responsible for data reduction and analysis.

(6) Generation of information which will serve as a guide in making new designs and in assessing their reliability.

(We are careful to avoid pretending that we in any way <u>measure</u> the reliability of the satellite.)

In attempting to reach the goals, despite the limitations, one must formulate a model of the failure pattern which we might expect to encounter. The test philosophy is then based on this concept. Our somewhat limited experience suggests that satellite failures fall into four categories:

(1) Early failures caused by a major design weakness.

(2) Early failures resulting from defects in material or workmanship.

(3) Random failures whose frequency of occurrence is a function of design and quality control.

(4) Wear-out failures.

Figure 3 illustrates this pattern which is also discussed by Lloyd and Lipow as being applicable to rocket engines.[8,9]

The systems test program is directed chiefly at eliminating those failures which arise from the first two causes. Although some insight is gained during the program into the pattern of random failure which may be expected, mathematical reliability analysis (despite its weaknesses) is probably the best guide to expected performance after infant mortality has been accounted for. Wear-out caused by exposure to mechanical environments is often covered in the test program. Wear-out caused by other factors such as surface deterioration under high vacuum is usually best attacked at a materials, component or subassembly level because of the extreme cost of conducting extended systems tests.

DESIGN QUALIFICATION (PROTOTYPE) TESTS

In a given satellite development program there may or may not be an electronic "bread board" of the complete system. In any case, the prototype is almost invariably the first unit in which the subassemblies appear together in their near final configuration and packaged in their proper relationship in the final structure. As indicated in Figure 3, many problems may be expected in the integration of the subassemblies into the prototype before producing a "working" satellite. At some point in the integration of the prototype, the pursuit of perfection in "bench" performance must be discarded in favor of the study of the design's performance in the face of the environmental rigors which it will encounter in the prelaunch, launch and space flight phases of its life. This is a conscious decision on the part of the project manager.

---

[8] Ibid., Page 416.

[9] It should be noted that this failure pattern has been attacked as unsupported by data by many authors. e.g. Cuthill, R. W., The Reliability Concept and Its Relationship to Performance. American Management Association Report.

Tests of the prototype system are directed toward the qualification of a design. It is in this series of tests that failures in the first category (major design weaknesses) should be eliminated. In attempting design-qualification with one sample, one must break with many traditional environmental test concepts. Overtesting is a necessity, but because of weight limitations, designs cannot be expected to have too great a margin.[10] Test to failure in several environments becomes a near impossibility on the time scale of a typical program. In the face of these problems, prototype test levels are usually established at what one might consider the 99% probability level. That is, there should be no more than one chance in a hundred that the flight unit will experience an environment more severe than that employed in prototype testing. The difficulties in setting a 99% level in a field as new as space flight are self-evident: adequate data usually does not exist.

FLIGHT UNIT TESTING

Tests of the flight units are directed toward the acceptance of a particular system for flight. Because only one prototype has been qualified, virtually no information is available on the variation which may be expected from unit to unit of the same design. Testing of the flight unit is intended then to discover failures in the second category: defects in material or workmanship. The exposure of flight hardware to severe environments is frequently attacked as tending to detract from its useful life. However, the purpose of the tests is valid, and they must be run. The key to the problem lies in the duration of the prototype tests. They must be long enough to give reasonable assurance that the design can survive both the environments imposed in acceptance testing of the flight units and those encountered in actual launching and flight. In the Pioneer V Program, for example, the prototype was subjected to its vibration schedule ten times to gain such assurance. Test levels for the flight units are usually set at the 95% probability level. That is, there is one chance in twenty that they will be exceeded when the actual launching takes place.

---

[10] One must also be aware of another trap in over-specifying environments. For example: if a design temperature is set arbitrarily high, you may force the use of low gain silicon transistors when half as many germanium transistors might have done the job. Here reliability may have been decreased rather than enhanced.

TEST LEVELS

Severity of applied environments has been set at the 99% level for qualification testing and the 95% level for acceptance testing. In view of the paucity of the available data, one can hardly justify thinking of these levels in statistical terms with carefully computed standard deviations and levels of confidence. Instead, the 95% level is usually taken to imply a condition which is supported by the most severe valid data which has been obtained. The 99% level is then set at an assumed mean value plus one and one half times the difference between the mean and the 95% level. This procedure is approximately correct mathematically for a normally distributed variable.[11]

THE TEST PLAN

Environmental testing of a satellite system is an integral part of the development cycle. As such it must be carefully pre-planned to assure that all factors of importance in a given program will be given proper consideration. Because environmental tests come just before launch, the time available for them inevitably shrinks as unexpected problems cause development program slippage while launching schedules remain inflexible. In this situation, a valid and comprehensive test plan approved and directed by management is a necessity to prevent errors and omissions during the drive to get acceptable flight units. Corners will be cut unless a clearly defined program has previously been established.

A test plan must first include the procedures by which the performance of the system under test is to be evaluated. In practice, there are usually three levels of such check-out. First, there is what might be termed an "in-line systems check". (In-line systems are rigorously defined as those whose individual failure would cause failures of the whole system. In practice, the term is usually applied to the power supply, encoding, telemetry and command receiver systems.) Such a check-out

---

[11] The 95% point of a cumulative normal is at 1.65σ. Then $1.5 \times 1.65\sigma = 2.47\sigma$. This is the 99.3% point.

procedure might be used, for example, during a vibration exposure. While survival of vibration is frequently all that is required, anomalies in performance as indicated by an in-line check made during vibration may be indicative of marginal conditions. Second, there is the "experiment exercise check". This procedure checks not only the in-line systems but also requires that the experiments be excited in some manner which causes their indicated output to leave the base line. This check might be used at some intermediate point in a vibration test during one of the many changes in set-up usually involved. Third, there is the "integrated systems test" during which experiments are not only exercised but also calibrated. This check is required before and after all major environmental conditionings.

The bulk of a test plan is devoted to the exposition of detailed procedures for the application of environmental conditioning to the particular satellite in question. While general specifications serve as a guide, they cannot be applied indiscriminately.[12] For example, acceleration levels depend on the weight of the satellite; and the manner of simulating the thermal environment in space depends upon the detailed techniques employed in the satellite for temperature control. In establishing the proper procedures for environmental test, a thorough knowledge of the satellite, the environment and the capabilities of the test equipment must be available. Improper test technique can lead to either the acceptance of an unsuitable system or the over-design of the system to pass an unrealistic test.

A final portion of the test plan is devoted to the criteria for "passing" a test, what procedures are to be followed in the event of certain classes of failures, and the manner in which failures are to be reported. The failure report system is usually part of a policy which transends a particular test program. However, the test plan must assure that this procedure is followed to permit the utilization of object lessons painfully learned today in the design of future satellites.

---

[12] e.g. General Environmental Test Specification for Delta Launched Spacecraft, Goddard Space Flight Center, Preliminary Draft, November 1962.

ENVIRONMENTAL EXPOSURES

The selection of the environmental exposures which are to be applied to a particular satellite during its test program must be made on the basis of an intimate knowledge of its purpose, functioning, and life cycle. Many exposures, levels and procedures which are meaningful in one application do not apply in others. Many tests included in an environmental test program are operational checks (e.g. a de-spin test) or are in the nature of property determinations (e.g. a moment of inertia measurement) rather than environmental exposures. These are included because of the complexity of the facilities involved.

The environments which should be considered in planning a satellite test program are illustrated in Figure 4. Assurance must be gained of the ability of the spacecraft to withstand all of these which are applicable in a given case. Some aspects may be covered by engineering calculation, e.g. radiation shielding. Other problems are treated on a subassembly basis, e.g. operation of bearings in ultra-high vacuum. Systems tests are directed toward those areas in which the interactions of subassemblies will be strongly felt. The discussion which follows will cover those environmental tests which are most often employed and are believed to be of the greatest significance.

Qualification testing of the prototype is directed toward the verification of the soundness of the system design as discussed above. Therefore, this portion of the test program is relatively broad in scope. Typically the following exposures are included: dynamic balancing and spin (if applicable), acceleration, vibration, shock, temperature, humidity, and thermal-vacuum.

Acceptance testing of the flight units is intended to uncover significant deviations of these samples from the qualified prototype design, chiefly in the areas of material and workmanship, and to verify that the particular unit is suitable for launching. Usually vibration, thermal-vacuum and final balancing are the only exposures employed.

Balance and Spin

Dynamic balancing of a spinning satellite is required to assure stability of the spin axis. Even for a stabilized satellite, measurement of its inertial properties and trim-balancing may be required to assure proper performance of the control system. A spin test (for a spinning satellite) is a natural adjunct to balancing since they are usually conducted on the same machine. While one thinks of satellites as operating in a zero-g environment, at 600 rpm the centripetal acceleration amounts to 10g/inch away from the center of rotation.

Acceleration

Acceleration tests are quite straightforward when the maximum acceleration which the vehicle can impart to a satellite of a given weight is known. A major problem is raised by the fact that most satellites are relatively long compared to the radius of available centrifuges. One must then consider the significance of the acceleration gradient which will exist in the satellite under test. A more subtle problem arises from the various possible combinations of axial and lateral accelerations which may exist simultaneously.

Vibration

Vibration testing is a compromise between many factors. First, our machines apply vibration in only one direction at a time in contrast to the actual flight condition. This results in extended test durations. Second, the vehicles currently in use inject both random and quasi-sinusoidal inputs to the satellite. Separate tests are frequently called for. Third, the final rocket stage and satellite mounting may exhibit a mechanical impedance comparable to that of the satellite. Test levels are then conditioned by the properties of the particular satellite. Fourth, the applicability of existing data has been seriously questioned from many quarters. A careful in-flight measurement program for vibration has been undertaken by GSFC in conjunction with its scientific satellite launchings.

Shock

There are two sources of shock for a satellite system: handling and rocket staging. Neither of these is especially severe in most cases. Normally a satellite is packaged with reasonable care to mitigate handling shock. Rocket staging rarely results in a pulse representing a velocity change of more than a very few feet per second. Typically, a drop test is used to verify resistance to shock.

Temperature

A temperature test is conducted on the prototype for two reasons. First, one must assure that the system will not be damaged by temperatures which will be encountered in handling, storage, or transit. If a controlled environment is provided by exotic packaging, this must be considered. Second, tests in a temperature chamber provide a first look at performance under expected space conditions. The presence of rapidly moving air, of course, depresses the temperatures which will be attained by power dissipating elements. Nevertheless, experience has shown the test to be very valuable.

Humidity

A relatively mild (compared to military specifications) humidity exposure (30°C with 95% RH for 24 hours) is usually employed with satellites. The test is used to assure that no permanent damage will be inflicted and to obtain an estimate of the "drying" time which may be involved when the satellite is returned to controlled conditions after exposure to high humidity. Damage to the satellite or excessive recovery times resulting from this test may dictate that protection from high humidity be provided the satellite at all times.

Thermal-Vacuum

Thermal-vacuum tests attempt to simulate the environment which the satellite will encounter in space with respect to temperature and pressure. Chamber pressures below 1×10^{-4} mm Hg are usually considered acceptable since air conduction is essentially negligible at this level. The study of surface effects which occur at much lower pressures (below 1×10^{-8} mmHg) is not a suitable objective for most overall systems tests.

(c) GSFC believes in testing a flight unit, designated a prototype, at approximately 150% of the flight acceptance tests.

(d) After the testing program, the system should remain intact and last minute changes avoided like the plague (firing jitters problem)."[13]

In reviewing our weekly reports for a one year period, we have culled references to some 266 malfunctions encountered during the testing phase on a dozen satellites and probes. All of these would of course not result in outright failure of the mission. It is (very crudely) estimated that 25% would have been in this "disaster" category.

Looking more closely at the data for five particular cases, we can make the following tabulation:

TABLE V

FAILURES DURING SYSTEMS TEST

(Summary for Five Spacecraft)

	Type of Failure		
Test Condition	Electrical	Mechanical	Total
Checkout	12	6	18
Vibration	20	14	34
Temperature	3	--	3
Vacuum	5	--	5
Thermal-Vacuum	51	3	54
Total	91	23	114

The high incidence of pre-test check-out failures is indicative of the pace of a satellite development program and the desire cited above to enter systems testing as quickly as possible. The failures under test follow about the pattern one would expect.

[13] Internal GSFC Memorandum dated January 21, 1963.

Simulation of the thermal environment is a much more complicated matter. Techniques range from controlling the temperature of the wall of the vacuum vessel (soak tests), through predicted temperature contour reproduction and heat flux simulation to full solar simulation. In choosing the technique to be employed in a given instance, a detailed knowledge of the thermal control system is required. Further, the distinction between running a performance test and verifying the thermal design must always be kept clearly in mind.

EXPERIENCE WITH EVALUATION PROGRAMS

The Goddard Space Flight Center has been responsible for the launching of some twenty-six satellites and space probes as described in the attached tabulation. These have ranged from the 79-pound Explorer X to the 458-pound Orbiting Solar Observatory. Eight of these satellites have been tested in-house, the remainder have been tested by the prime contractor under Goddard supervision. These programs have moulded much of the philosophy discussed above.

In general, these satellites have been highly successful. They range from six successful TIROS satellites in six attempts to the highly publicized failure of one half of the Relay Communications Satellite. (Redundancy paid off.)

The question now arises as to the contribution of the environmental testing program to these successes. In discussing the reasons for Goddard's success, Dr. J. W. Townsend, Assistant Director for Space Science and Satellite Applications, has said:

> "The principal cornerstone of our development philosophy has been our belief and reliance in a strong testing program.
>
> (a) GSFC believes in the FULL SYSTEMS test approach. Every reasonable attempt should be made to test the <u>entire system</u> under as realistic conditions as possible and as early in the development cycle as feasible.
>
> (b) GSFC believes in 100% flight acceptance testing at expected average flight levels plus 2 sigma (95% level).

From another point of view, we have always had much more difficulty with prototype qualification than anyone expected. However, we have then had much less trouble with the flight units than most people feared after the prototype experience.

ADEQUACY OF TEST LEVELS

Vibration

As discussed earlier, there is considerable uneasiness over the proper levels of vibration to be applied to a given satellite. In-flight success has indicated that they are probably sufficiently high. The failure in flight of one non-in-line subassembly which had failed to qualify in vibration but which was flown anyway suggests that the levels are not excessive. It is believed that the data gathered by our in-flight measurements program will verify these conclusions. The results so far tentatively indicate that our test levels are somewhat low at low frequencies where vehicle structural modes are found and somewhat high at intermediate frequencies.

An unexpected failure of one experiment probably during the powered flight phase of the Ariel I launching suggests that our testing did not adequately cover the combined effects of acceleration and vibration. This area of combined environments is one in which we feel a certain weakness.

Thermal-Vacuum

There are problems in both level and duration of thermal-vacuum testing.

Recent experience, particularly with Explorer XIV, has indicated that our ability to predict temperatures on the basis of engineering calculation is not particularly good for complicated satellite geometrics.[14] This is pushing us strongly toward solar simulation as the desired test method. However, here we find the test equipment marginal at best.

In the matter of test duration, we have the quandry of when to stop testing. This is touched on by Lloyd and Lipow[15]

---

[14] The Jet Propulsion Laboratory encountered a similar problem in their Mariner II Venus fly-by.

[15] Lloyd & Lipow, Op. Cit., Page 416 and Chapter 16.

Table VI - Solar Powered Satellite Lifetime (Continued)

Name	Date Launched	Silent	Life (Months)	Remarks
Alouette	Sep. 29, '62	Active	3+	Good data being received. Solar Cell output diminished by radiation effect. Wt. 320 Lb., 3 Expr.
OSO - I	Mar. 7, '62	Active	10+	Data still being received. Some problem in positioning control. Wt. 458 Lb.; 13 Expr.

* * * * *

in their discussion of the development of a test program for a liquid rocket engine. In this case, they were able to project desirable test duration and make reliability estimates on the basis of many tests (~100) of suitably similar devices of the same design. In our case, we have had one similar device: the prototype.

Experience with the more sophisticated satellites which we are now flying indicates we are not achieving the one year life which we nominally feel is desirable. Table VI shows typical performance. We are attacking this problem on both the design and testing levels. (It might also be noted that we are including timers in many satellites to shut them off after one year to clear the communications channels.)

From the testing point of view there is another duration problem. It will be recalled that our failure model proposes that initial testing be long enough to eliminate "infant" faults. Figure 5[16] shows our experience in this regard on three satellites. These data show that we are still having failures at a significant rate as the test ends. Extending the required duration of thermal-vacuum tests is under serious consideration.

UTILIZATION OF EXPERIENCE

Currently, the utilization on the next program of experience gained in the development and evaluation of a previous satellite is a significant problem. The difficulty in this area is largely caused by the fact that the state-of-the-art is progressing so rapidly that none but the most recent experience has application. The problems in instant acquisition, digestion and dissemination of such information are obviously manifold. One can only say that we are constantly trying to improve the procedures and mechanisms used for this purpose.

---

16 Timmins, A. R. and Rosette, K. L., Experience in Thermal-Vacuum Testing Earth Satellites at Goddard Space Flight Center. (Proceedings of the Institute of Environmental Sciences) April 1963 - (to be published).

TABLE VI

SOLAR POWERED SATELLITE LIFETIME

Name	Date Launched	Silent	Life (Months)	Remarks
Vanguard I	Mar. 17, '58	Active	57+	Oldest active satellite. First use of Solar Cell. Wt. 3 Lbs.; 2 Expr.
Explorer VI	Aug. 7, '59	Oct. 6, '59	2	Decayed from orbit July 1961. Wt. 143 Lb.; 8 Expr.
Explorer VII	Oct. 13, '59	Aug. 24, '61	26	Tracking Beacon ceased on silent date. 20 megacycle transmitter still active. Clock failed on launch (?). Wt. 92 Lb.; 6 Expr.
Explorer XI	Apr. 27, '61	Dec. 6, '61	7	All experiments working until silent date. Tape recorder never functioned. Wt. 82 Lb.; 6 Expr.
Explorer XII	Aug. 15, '61	Dec. 6, '61	4	Abrupt stop in transmission. Wt. 83 Lb.; 10 Expr.
Explorer XIV	Oct. 2, '62	Jan. 11, '63	3+	Encoder started malfunctioning Jan. 11, 1963. Good data until then. Wt. 89 Lb.; 6 Expr.
Explorer XV	Oct. 27, '62	Active	2+	Good data being received on artificial radiation belt. Wt. 100 Lb.; 7 Expr.
Ariel I	Apr. 26, '62	Active	4+	Showed undervoltage problems in Aug. 1962. Encoder malfunctioned at times. Some data still being received. Wt. 132 Lb.; 7 Expr.

SUMMARY

In the foregoing, an attempt has been made to follow the rational used in establishing an environmental test program and to fit this program into the overall satellite reliability picture. Perhaps the most distinctive feature of a satellite test program is that stringent environmental tests of the actual flight units are conducted. The success of the approach is demonstrated by highly successful satellites in orbit.

Goddard Space Flight Center Satellites and Space Probe Projects

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
EXPLORER VI 1959 Delta I S-2	Aug. 7, 1959	Oct. 6, 1959	Thor-Able AMR	To measure three specific radiation levels of Earth's radiation belts; test scanning for Earth's cloud-cover; map Earth's magnetic field; measure micrometeorites; study behavior of radio-waves.	Equipment to measure radiation levels; tv-type scanner; micrometeorite detector; two types of magnetometer and devices for space communication experiments.	12 1/2 hours	156	26,357	Dr. John C. Lindsay Dr. John C. Lindsay	Triple coincidence telescopes	J. A. Simpson C. Y. Fan P. Meyer	U. of Chicago	Orbit achieved. All experiments performed. First complete televised cloud-cover picture was obtained. Detected large ring of electrical current circling Earth; complete map of Van Allen radiation belt obtained. Weight: 142 lbs. Power: Solar Life: 2 months
										Scintillation counter	T. A. Farley Allen Rosen C. P. Sonnett	Space Technology Laboratories	
										Ionization chamber Geiger counter	J. Winckler	U. of Minn.	
										Spin-coil magnetometer	E. J. Smith D. L. Judge	STL	
										Fluxgate magnetometer	P. J. Coleman	STL	
										Aspect sensor		STL	
										Image-scanning television system		STL	
										Micrometeorite detector		Cambridge Research/STL	
VANGUARD III 1959 Eta	Sept. 18, 1959	Dec. 12, 1959	Vanguard AMR	To measure the Earth's magnetic field, x-radiation from the sun and several aspects of the space environment through which the satellite travels.	Proton precisional magnetometer, ionization chambers for solar x-rays, micrometeor detectors and thermistors.	130	319	2,329		Magnetometer	J. P. Heppner	GSFC	Orbit achieved. Provided comprehensive survey of earth magnetic field over area covered; surveyed location of lower edge of Van Allen Radiation Belt. Accurate count of micrometeorite impacts. Weight: 100 lbs. including attached 3rd stage. Power: Battery Life: 85 days
										Ionization Chambers	H. Friedman	NRL	
										Environmental Measurements	H. E. LaGow	GSFC	
EXPLORER VII S-1a	Oct. 13, 1959	Aug. 24, 1961	Juno II AMR	Variety of experiments, including solar ultraviolet; x-ray; cosmic-ray, Earth radiation and micrometeor experiments.	Sensors for measurements of Earth-Sun heat balance; Lyman-Alpha and x-ray solar radiation detectors; micrometeor detectors, Geiger-Mueller tubes for cosmic ray count; ionization chamber for heavy cosmic rays.	101.33	342	680	H. LaGow	Thermal radiation balance	V. Suomi	U. of Wisc.	Orbit achieved. Provided significant geophysical information on radiation and magnetic storms; demonstrated method of controlling internal temperatures; first micrometeorite penetration of a sensor in flight. Weight: 91.5 lbs. Power: Solar Life: 26 months
										Solar x-ray and Lyman-alpha	H. Friedman R. W. Kreplin T. Chubb	NRL	
										Heavy cosmic radiation	G. Groetzinger P. Schwed M. Pomerantz	Martin Co. Bartol Research	
										Radiation and solar-proton observation	J. Van Allen G. Ludwig H. Whelpley	St. U. of Iowa	
										Ground-based ionospheric observations	G. Swenson Dr. C. Little G. Reid O. Villard, Jr. W. Ross W. Dyke	U. of Illinois Nat. Bu. of Stand. U. of Alaska Stanford Univ. Penn State Univ. Linfield Res. Inst.	
										Micrometeorite penetration experiment	H. LaGow	GSFC	

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
PIONEER V 1960 Alpha	Mar. 11, 1960	June 26, 1960	Thor-Able AMR	Investigate interplanetary space between orbits of Earth and Venus, test extreme long range communications, study methods for measuring astronomical distances.	High intensity radiation counter, ionization chamber Geiger-Mueller tube to measure plasmas, cosmic radiation and charged solar particles. Magnetometer and micrometeorite temperature measurements.	311.6 days	Perihelion 74.9 million from sun	Aphelion 92.3 million from sun	Dr. John C. Lindsay Dr. John C. Lindsay	Triple coincidence proportional counter cosmic-ray telescope	J. Simpson	U. of Chicago	Highly successful exploration of interplanetary space between orbits of Earth and Venus; established communication record of 22.5 million miles on 6/26/60; made measurements of solar flare effects, particle energies and distribution, and magnetic field phenomena in interplanetary space. Weight: 94.8 lbs. Power: Solar Life: 3 months
										Search-coil magnetometer and photoelectric cell aspect indicator	D. Judge	STL	
										Ionization chamber and G-M tube	J. Winckler	U. of Minn.	
										Micrometeorite counter	E. Manring	AFCRC	
TIROS I Beta 1960 A-1	April 1, 1960	June 12, 1960	Thor-Able AMR	Test of experimental television techniques leading to eventual worldwide meteorological information system.	One wide and one narrow angle camera, each with tape recorder for remote operation. Picture data can be stored on tape or transmitted directly to ground stations.	99.1	428.7	465.9	W. G. Stroud (GSFC) H. Butler (Army)	TV camera systems (2)			Provided 1st global cloud-cover photographs (22,952 total) from near circular orbit. Weight: 270 lbs. Power: Solar Life: 72 days
ECHO I 1960 Iota	Aug. 12, 1960	Still in Orbit	Thor-Delta AMR	Place 100 foot inflatable sphere into orbit.	Two Minitrack tracking Beacons on sphere.	118.3	945	1,049	Robert J. Mackey				Demonstrated use of radio reflector for global communications, numerous successful transmissions. Visible to the naked eye. Weight: 132 lbs. (including inflation powder). Power: Passive Life: Still in Orbit
EXPLORER VIII 1960 Xi S-30	Nov. 3, 1960	Dec. 28, 1960	Juno II AMR	Investigation of the ionosphere by direct measurement of positive ion and electron composition; collect data on the frequency momentum and energy of micrometeorites impacts; establish the attitude of the base of the exosphere.	RF impedance probe using a 20-foot dipole sensor; single grid ion trap; four multiple-grid ion traps; Langmuir probe experiment; rotating shutter electric field meter; micro plier; micrometeorite microphone; thermistors for reading internal and surface temperatures of the space craft; and despin mechanisms to reduce spin from 450 to 30 rpm.	112.7	258	1423	Robert E. Bourdeau Robert E. Bourdeau	RF impedance	J. Cain	GSFC	Measured the electron density, temperature, ion density and composition, and charge on the satellite in the upper ionosphere. The micrometeorite influx rate was measured. Weight: 90.14 lbs. Power: Battery Life: 55 days
										Ion traps	R. Bourdeau G. Serbu E. Whipple J. Donnelly	GSFC	
										Langmuir probe	R. Bourdeau G. Serbu E. Whipple J. Donnelly	GSFC	
										Rotating-shutter electric field meter	J. Donnelly	GSFC	
										Micrometeorite photomultiplier	M. Alexander K. McCracken O. Berg	GSFC	
										Micrometeorite microphone	M. Alexander K. McCracken	GSFC	

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
TIROS II 1960 Pi 1 A-2	Nov. 23, 1960	Feb. 7, 1961	Delta AMR	Test of experimental television techniques and infrared equipment leading to eventual world-wide meteorological information system.	Includes one wide and one narrow angle camera, each with tape recorder for remote operation; infrared sensors to map radiation in various spectral bands; attitude sensors; experimental magnetic orientation control.	98.2	406	431	Dr. R. Stampfl	TV camera systems (2) Widefield radiometer experiment Scanning radiometer experiment			Orbit achieved. Narrow-angle camera and IR instrumentation sent good data. Transmitted 36,156 pictures. Still operative. Weight: 277 lbs. Power: Solar Life: 76 days
EXPLORER IX 1961 Delta I S-56a	Feb. 16, 1961	Passive Satellite	Scout Wallops Island	To study performance, structural integrity and environmental conditions of Scout research vehicle and guidance controls system. Inject inflatable sphere into Earth orbit to determine density of atmosphere.	Radio beacon on balloon and in fourth stage.	118.3	395	1605					Vehicle functioned as planned. Balloon and fourth-stage achieved orbit. Transmitter on balloon failed to function properly requiring optical tracking of balloon. Weight: 80 lbs. Power: Passive Life:
EXPLORER X 1961 Kappa P-14	Mar. 25, 1961	Mar. 27, 1961	Thor-Delta AMR	Gather definite information on earth and interplanetary magnetic fields and the way these fields affect and are affected by solar plasma.	Includes rubidium vapor magnetometer, two fluxgate magnetometers, a plasma probe and an optical aspect sensor.	112 hours	100	186,000	Dr. J. P. Heppner Dr. J. P. Heppner	Rubidium-vapor magnetometer & fluxgate magnetometers Plasma probe Spacecraft attitude experiment	J. P. Heppner T. L. Skillman C. S. Scearce H. Bridge F. Scherb B. Rossi J. Albus	GSFC MIT GSFC	Probe transmitted valuable data continuously for 52 hours as planned. Demonstrated the existence of a geomagnetic cavity in the solar wind and the existence of solar proton streams transporting solar interplanetary magnetic fields past the earth's orbit. Weight: 79 lbs. Power: Battery Life: 52 hrs.
EXPLORER XI 1961 Nu I S-15	Apr. 27, 1961	Dec. 6, 1961	Juno II AMR	Orbit a gamma ray astronomy telescope satellite to detect high energy gamma rays from cosmic sources and map their distribution in the sky.	Gamma ray telescope consisting of a plastic scintillator, crystal layers and a Cerenkov detector; sun and earth sensors; micrometeorite shields; temperature sensor; damping mechanism.	108.1	304	1113.2	Dr. J. Kupperian, Jr. Dr. J. Kupperian, Jr.	Gamma-ray telescope	W. Kraushaar G. Clark	MIT	Orbit achieved. Detected first gamma rays from space. Directional flux obtained. Disproved one part of "steady state" evolution theory. Weight: 82 lbs. Power: Solar Life: 7 months
TIROS III 1961 Rho I A-3	July 12, 1961	Dec. 4, 1961	Thor-Delta AMR	Develop satellite weather observation system; obtain photos of Earth's cloud cover for weather analysis; determine amount of solar energy absorbed, reflected and emitted by the Earth.	Two wide-angle cameras, two tape recorders and electronic clocks, infrared sensors, five transmitters, attitude sensors, magnetic attitude coil.	100.4	461.02	506.44	R. Rados	Omnidirectional radiometer Widefield radiometer experiment Scanning radiometer experiment TV cameras (2)	V. Suomi	U. of Wisc.	Orbit achieved. Cameras and IR instrumentation transmitted good data. Transmitted 35,033 pictures. First hurricane covering international program. Weight: 285 lbs. Power: Solar Life: 145 days
EXPLORER XII 1961 Upsilon I S-3	Aug. 15, 1961	Dec. 6, 1961	Thor-Delta AMR	Investigate solar wind, interplanetary magnetic fields, distant portions of Earth's magnetic field, energetic particles in interplanetary space and in the Van Allen Belts.	Ten particle detection systems for measurement of protons and electrons and three orthogonally mounted fluxgate sensors for correlation with the magnetic fields, optical aspect sensor, and one transmitter. Telemetry is PFM and transmits continuously.	26.45 hours	180	47,800	P. Butler Dr. F. McDonald	Proton analyzer Magnetometer Cosmic ray Ion-electron detector Solar cell	M. Bader L. Cahill B. O'Brien F. B. McDonald L. Davis G. Longanecker	Ames Research Center U. of New Hampshire St. U. of Iowa GSFC GSFC GSFC	Orbit achieved; all instrumentation operated normally. Ceased transmitting on Dec. 6, 1961, after sending 2568 hours of real time data. Provided significant geophysical data on radiation and magnetic fields. Weight: 83 lbs. Power: Solar Life: 4 months

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
EXPLORER XIII 1961 Chi	Aug. 25, 1961	Aug. 27, 1961	Scout Wallops Island	Testing performance of the vehicle and guidance; investigation, nature and effects on space flight of micrometeoroids.	Micrometeroids impact, detectors, transmitters.	97.5	74	722	C. T. D'Aiutolo	A cadmium sulphate photoconductor experiment. A wire grid experiment.	M. W. Alexander L. Secretan	GSFC	Orbit was lower than planned. Re-entered August 27, 1961. Weight: 187 lbs. including 50 lb. 4th stage and 12 lb. transition section. Power: Solar Life: 2 days
P21 ELECTRON DENSITY PROFILE PROBE P-21	Oct. 19, 1961	Oct. 19, 1961	Scout Wallops Island	To measure electron densities and to investigate radio propagation at 12.3 and 73.6 Mc under daytime conditions.	Continuous wave propagation experiment for the ascent portion of the trajectory, and an RF probe technique for the descent.		N/A	N/A 4261	John E. Jackson Dr. S. J. Bauer	RF probe	H. Whale	GSFC	Probe achieved altitude of 4261 miles and transmitted good data. Electron density was obtained to about 1500 miles, making the first time such measurements have been taken at this altitude. Weight: 94 lbs. Power: Battery Life: Hours
TIROS IV 1962 Beta A-9	Feb. 8, 1962	June 19, 1962	Delta AMR	Develop principles of weather satellite system; obtain cloud and radiation data for use in meteorology	Two TV camera systems with clocks and recorders for remote pictures, infrared sensors, heat budget sensors, magnetic orientation control horizon sensor, north indicator.	100.4	471	525	R. Rados	Omni-directional radiometer Widefield radiometer experiment Scanning radiometer experiment TV camera systems (2)	V. Suomi	U. of Wisc.	Orbit achieved. All systems transmitting good. Tegea Kinoptic lens used on one camera. Elgeet lens on the other. Support to Project Mercury. Weight: 285 lbs. Power: Solar Life: 131 days
ORBITING SOLAR OBSERVATORY OSO-1 1962 Zeta S-16	Mar. 7, 1962	Active	Delta AMR	Placed satellite in Earth orbit to measure solar electromagnetic radiation in the ultra-violet, x-ray and gamma ray regions; investigated effect of dust particles on surfaces of spacecraft.	Devices to conduct 13 different experiments for study of solar electromagnetic radiations; investigate dust particles in space and thermo radiation characteristics of spacecraft surface materials.	96.15	343.5	369	Dr. John C. Lindsay	X-ray spectrometer	W. Behring W. Neupert	GSFC	Orbit achieved. Experiments transmitting as programmed. Weight: 458 lbs. Power: Solar Life: Active
									Dr. John C. Lindsay	0.510 Mev gamma-ray monitoring; 20-100 kev x-ray monitoring; 1-8A X-ray monitoring	K. Frost W. White	GSFC	
										Dust particle experiment	M. Alexander C. McCracken	GSFC	
										Solar radiation experiment solar ultraviolet	W. White K. Hallam	GSFC	
										Solar gamma rays, high energy distribution	W. White K. Frost		
										Solar gamma rays, low energy distribution	J. R. Winkler L. Peterson	U. of Minn.	
										Solar gamma rays, high energy distribution	M. Savedoff G. Fazio	U. of Rochester	
										Neutron monitor experiment	W. Hess	U. of Calif.	
										Lower Van Allen belt	S. Bloom	U. of Calif.	
										Emissivity stability of surfaces in a vacuum environment	G. Robinson	Ames Research Center	

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.
As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Sattute Miles	Orbital Elements Apogee Sattute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
P21A ELECTRON DENSITY PROFILE PROBE P-21A	Mar. 29, 1962	Mar. 29, 1962	Scout Wallops Island	To measure electron density profile, ion density and type of ions in the atmosphere.	A continuous wave propagation experiment to determine electron density and associated parameters of ionosphere. A swept frequency probe for direct measurements of electron density and a positive ion experiment to determine ion concentration under night time conditions.		N/A	N/A 3910	John E. Jackson Dr. S. J. Bauer	CW propagation RF probe Ion traps	S. Bauer H. Whale R. Bordeau E. Whipple J. Donnelly G. Serbu	GSFC GSFC GSFC	Afforded night-time observations. Characteristics of the ionosphere differ drastically from daytime state when the ionosphere is much cooler. See (P-21) Weight: 94 lbs. Power: Battery Life: Hours
ARIEL INTER-NATIONAL SATELLITE (UK 1) S-51	April 26, 1962	Active	Delta AMR	To study ionosphere and cosmic rays relationship.	Electron density sensor, electron temperature gauge, solar aspect sensor, cosmic ray detector, ion mass sphere, Lyman-Alpha gauges, tape recorder, X-ray sensors.	100.9	242.1	754.2	R. C. Baumann Robert E. Bourdeau	Electron density sensor Electron temperature gauge Solar aspect sensor Cosmic ray detector Ion mass sphere Lyman Alpha gauge			Orbit achieved. All experiments except Lyman-Alpha transmitting as programmed. First international satellite. Contains six British experiments, launched by American Delta vehicle. Weight: 150 lbs. Power: Solar Life: Active
TIROS V 1962 Alpha Alpha One A-50	June 19, 1962	Active	Delta AMR	Develop principles of weather satellite system; obtain cloud cover data and radiation data for use in meteorology.	Two TV camera systems with tape recorders for recording remote picture areas, infra-red sensors, magnetic orientation control, horizon sensor, north indicator.	100.5	367	604	R. Rados	TV camera systems (2)			Launched at a higher inclination (58°) than previous TIROS satellites to provide greater coverage. Time of launch chosen to include normal hurricane season for South Atlantic. IR sensor inoperative, all other systems transmitting good. Weight: 285 lbs. Power: Solar Life: Active
TELSTAR NO. 1	July 10, 1962	Active	Delta AMR	Joint AT & T investigation of wide-band communications.	The system provides for TV, radio, telephone and data transmission via a satellite repeater system.	157.8	592.6	3503.2	C. P. Smith, Jr.				Orbit achieved. Television and voice transmissions were made with complete success. Bell Telephone Laboratories provide spacecraft and ground stations facilities. Government to be reimbursed for cost incurred. Weight: 175 lbs. Power: Solar Life: Active

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
ALOUETTE SWEPT FREQUENCY TOPSIDE SOUNDER S-27	Sept. 29, 1962	Active	Thor Agena PMR	To measure the electron density distribution in the ionosphere at altitudes between 180 miles and 620 miles. To study for a period of a year the variations of electron density distribution with time of day and with latitude, under varying magnetic and auroral conditions; and with particular emphasis on high latitude effects. To determine electron densities in the vicinity of the satellite by means of galactic noise measurements, and to make observations of related physical phenomena; such as the flux of energetic particles.	A swept frequency pulsed sounder covering the frequency range 1.6 to 11.5 Mc.	105.4	620	638	John E. Jackson	Diurnal hour to hour change Electron density Ionization Whistler experiment			The Alouette satellite is a project of the Canadian Defence Research Board. The project is part of NASA's Topside Sounder Program. This will be NASA's first satellite to be launched from the Pacific missile Range. 80.84 inclination Alouette is not spacecraft designed and built by any other country than the U.S. and USSR. Weight: 320 lbs. Power: Solar Life: Active
TIROS VI A-51	Sept. 18, 1962	Active	Delta AMR	To study cloud cover and earth heat balance; measurement of radiation in selected spectral regions as part of a program to develop meteorological satellite systems.	Two TV camera systems (78° and 104° Lens), clocks and tape recorders for remote operation, infrared and attitude sensors, magnetic attitude coil.	98.73	425	442	R. Rados	Medium angle camera failed Dec. 1, 1962 after taking 1,074 pictures.			Inclination 58.3°, velocity perigee 16,822, apogee 16,756. Weight: 300 lbs. Power: Solar Life: Active
ENERGETIC PARTICLES SATELLITE EXPLORER XIV S-3a	Oct. 2, 1962	Active	Delta AMR	To describe the trapped corpuscular radiation, solar particles, cosmic radiation and the solar winds, and to correlate the particle phenomena with the magnetic field observations.	An octagon-walled platform, fabricated from nylon honeycomb and fiberglass, houses most of the instruments, experiments, and electronics. The transmitter is located in the base of the space craft. A magnetometer package containing three orthogonally mounted magnetometers and calibration coils is located on a boom forward of the platform. Telemetry is PFM and transmits continuously.	37 hours (2185 minutes)	175	61,226	Paul G. Marcotte Dr. Frank B. McDonald	Cosmic ray experiment Ion detector experiment Solar cell experiment Probe analyses Trapped radiation experiment Magnetometer experiment	F. McDonald L. Davis G. Longanecker M. Bader B. O'Brien L. Cahill	GSFC GSFC GSFC Ames St. U. of Iowa U. of New Hampshire	Velocity of apogee 1507 mph, perigee 23,734 mph. Inclination to Equator 33°. Weight: 86 lbs. Power: Solar Life: Active

Goddard Space Flight Center Satellites and Space Probe Projects--Cont.

As of December 1962

Designation	DATE Launch	DATE Silent	Launch Vehicle & Site	Objectives	Instrumentation	Period Minutes	Orbital Elements Perigee Statute Miles	Orbital Elements Apogee Statute Miles	Project Manager & Project Scientist	Experiment	Experimenter	Affiliation	Remarks
EXPLORER XV S 3-b	Oct. 27, 1962	Active	Delta AMR	To study new artificial radiation belt created by nuclear explosions.	Similar to Explorer XII.	5 hours (C. 315 min.)	195	10,950	Dr. John W. Townsend; Dr. Wilmot Hess	Electron energy distribution	W. Brown, V. Desai	Bell Telephone Laboratories	Good data being received on artificial radiation belt. Weight: 100 lbs. Power: Solar Life: Active
										Omnidirectional detector	C. McIlwain	U. of Calif.	
										Angular distributor	W. Brown	Bell Telephone Laboratories	
										Directional detector	C. McIlwain	U. of Calif.	
										Ion-electron detector	L. Davis	GSFC	
										Magnetic field experiment	L. Cahill	U. of New Hampshire	
										Solar cell gauge	H. K. Gummel	Bell Telephone Laboratories	
RELAY A-16	Dec. 13, 1962	Active	Delta AMR	To investigate wideband communications between ground stations by means of low-altitude orbiting space craft. Communications signal to be evaluated will be an assortment of television signals, multi-channel telephony and other communications.	The spacecraft will contain an active communications repeater to receive and retransmit communications between the U.S. and Europe, and an experiment to assess radiation damage to solar cells.	185.09	819.64	4612.18	Joseph Berliner; Dr. R. C. Waddel	First TV transmission U.S. to France, Jan. 9, 1963			Wideband Stations: Rumford, Maine; Pleumeur-Bodou, France; Goonhilly, England; Weilhelm, W. Germany. Narrow band stations: Nutley, N. J., Rio de Janeiro, Brazil. Inclination 47.47°. Weight: 158 lbs. Power: Solar Life: Active

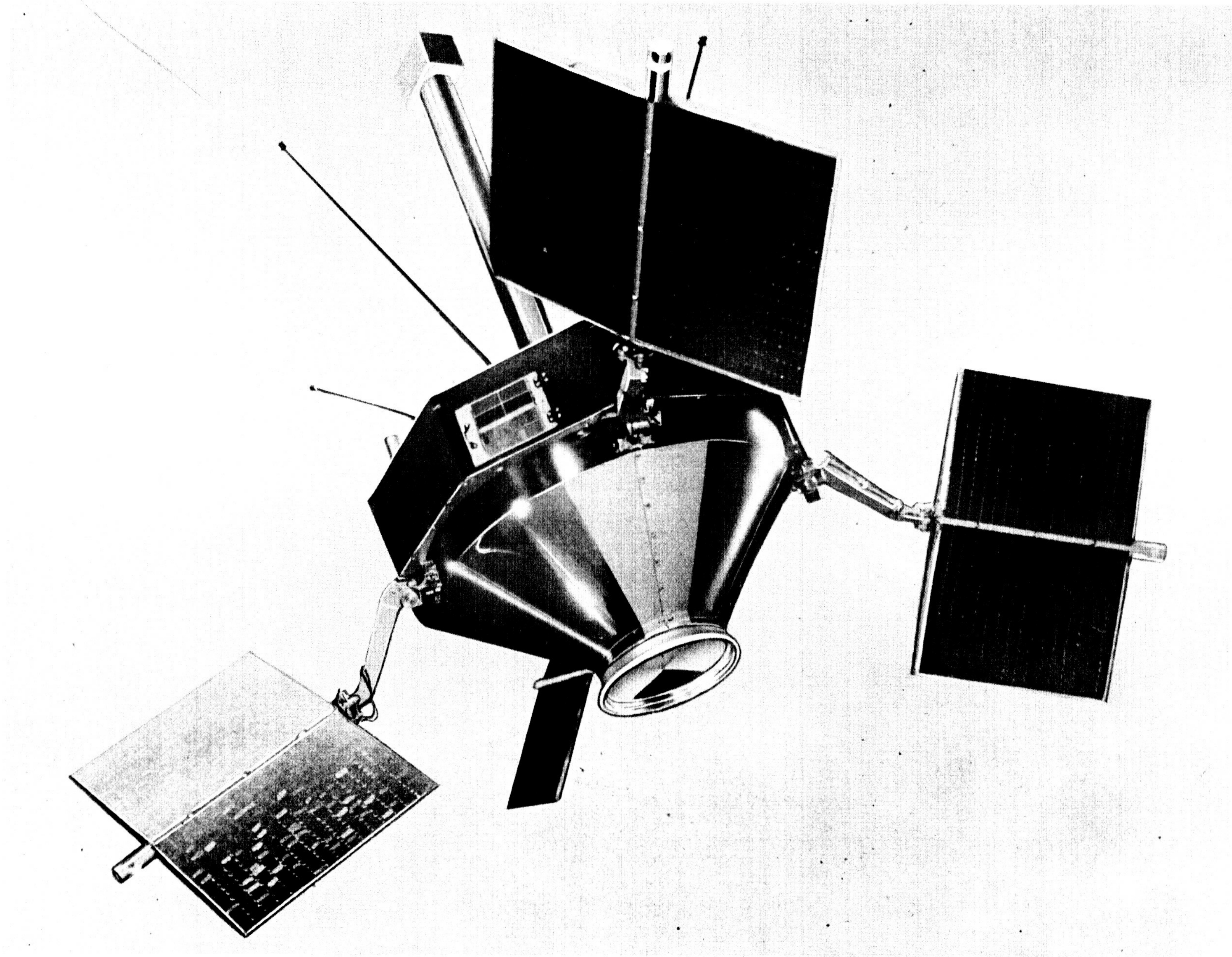

Figure 1. Explorer XII

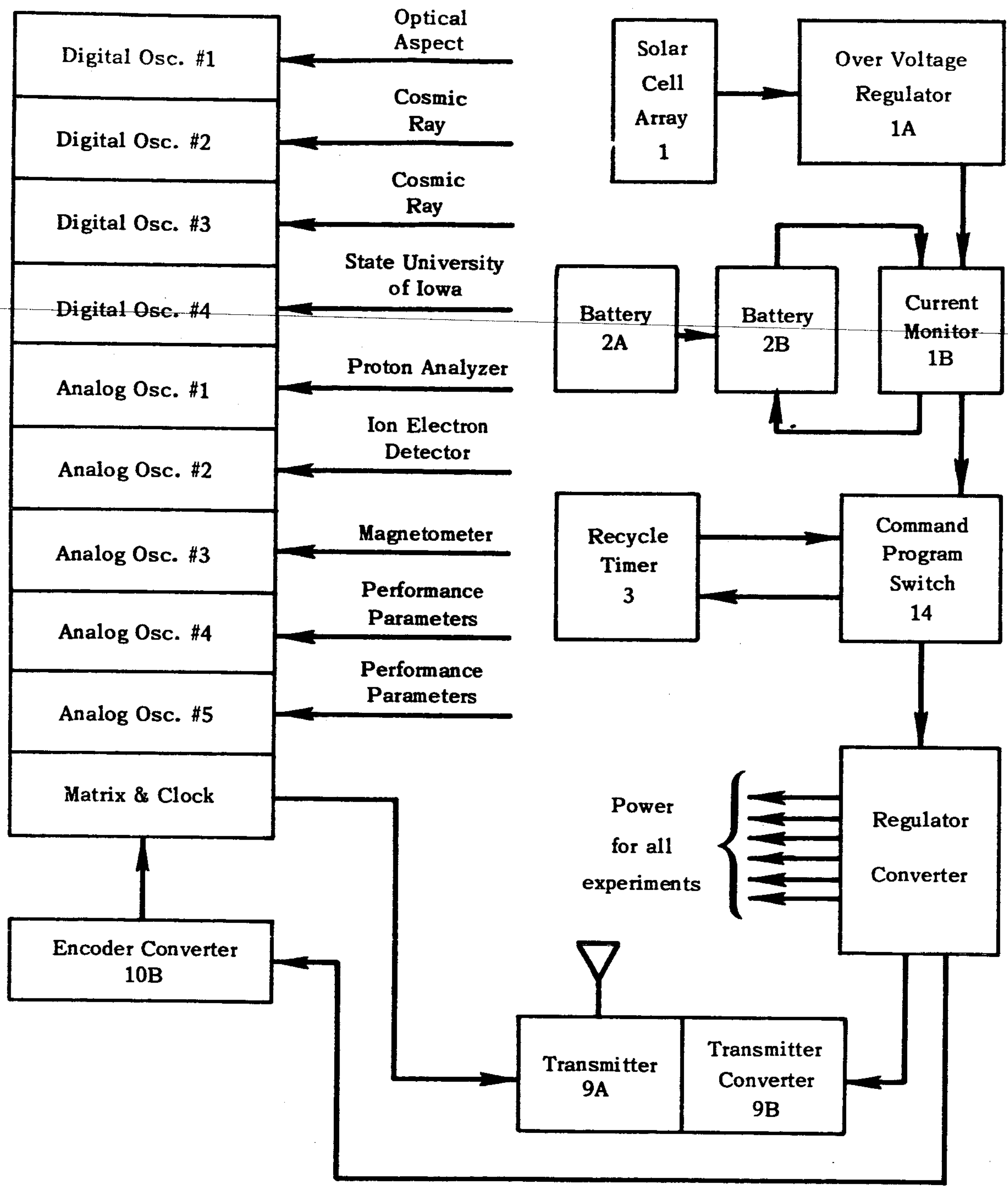

Figure 2. Block Diagram Of Explorer XII System

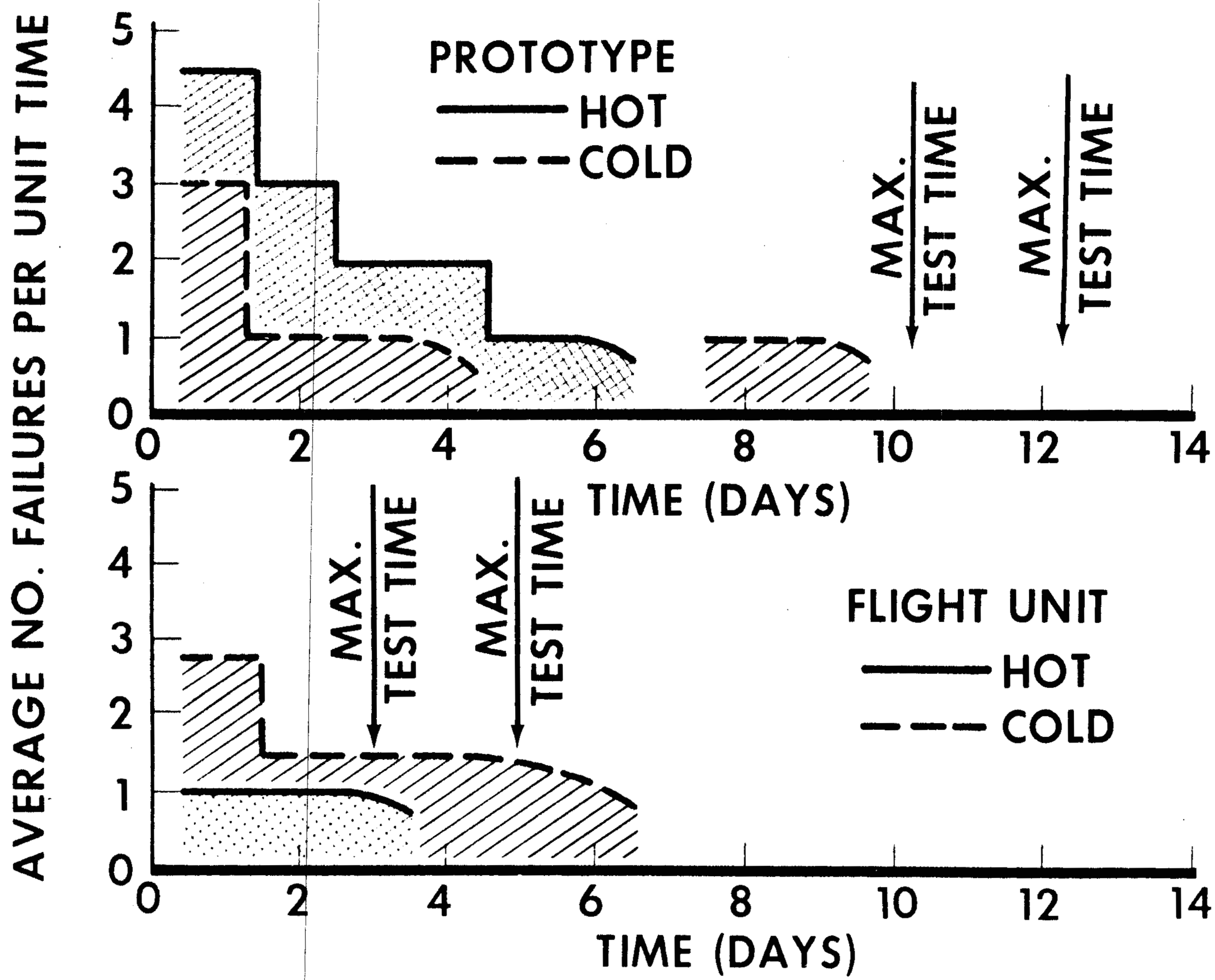

Figure 5. Experience In Thermal-Vacuum Testing

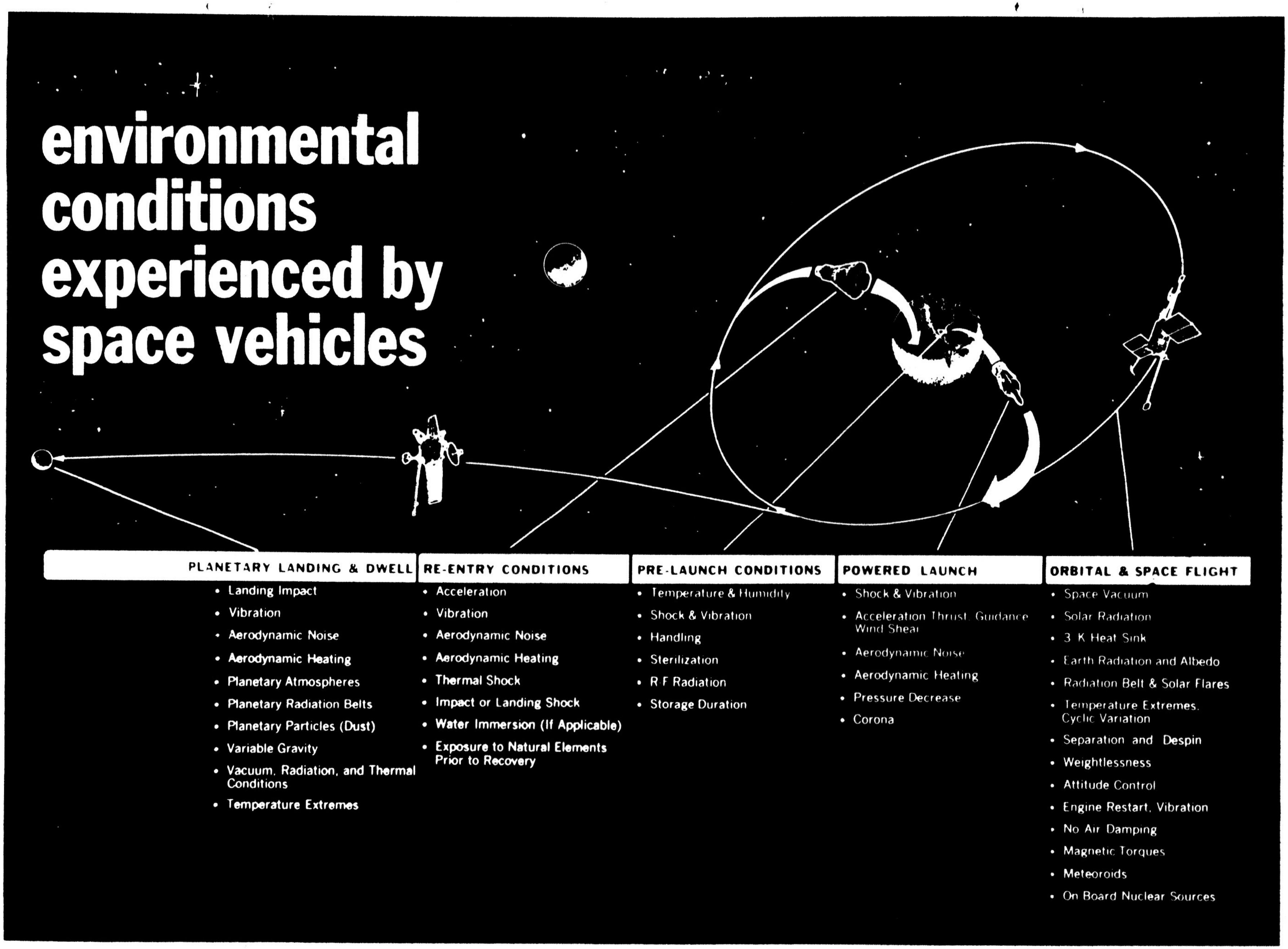

Figure 4. Environmental Conditions Experienced By Space Systems

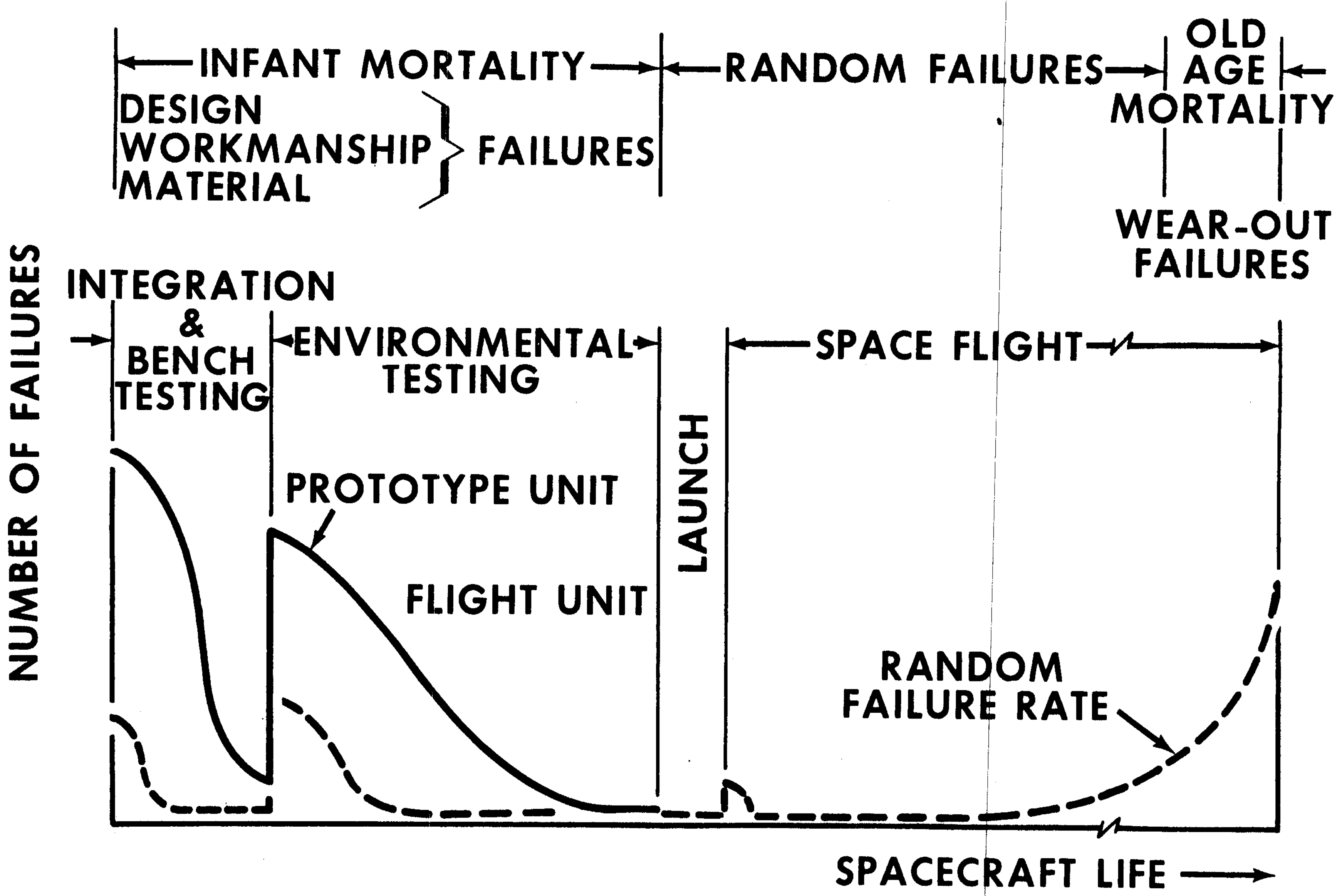

Figure 3. Failure Pattern